META'14 - Singapore

The 5th International Conference on Metamaterials, Photonic Crystals and Plasmonics

Program

May 20 – 23, 2014
Singapore

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08:30 : Invited talk
Wide band transparent metallo-dielectric nanowires at telecommunications wavelengths: more transparent than glass
R. Paniagua-Dominguez, Diego Abujetas, Luis Froufe-Perez, Juanjo Saenz, J. Sanchez-Gil

In this paper we propose metallo-dielectric nanowires (NW) as structures suitable to construct electrically conducting nanowires which are transparent to infrared radiation at wavelengths used in telecommunication applications. We show that the transparency of metal NWs covered with high permittivity dielectric materials are optimal structures regarding fabrication imperfections, variations in the angle of incidence and polarization of the incoming radiation. The bandwidth of the transparent region entirely covers the near IR telecommunications range.

08:50 : Invited talk
Absorption and scattering efficiency of Core/Shell plasmonic nanowire structures
Hossein Alisafaee, Michael Fiddy

We investigate the efficiency of absorption and scattering in standing nanowire array of semiconductor materials. Enhancement of absorption using plasmonic nanoparticles for higher efficiencies is studied. Core-shell nanoparticles of gold and silicon are used to collect light for an effective coupling to the semiconductor nanowire array. The wide band absorption of the solar spectrum (Air Mass 1.5 Global) is considered utilizing the tunning capability of core/shell plasmonic nanoarticles.

09:10 : Invited talk
Dielectric particles with electric and magnetic dipole resonances: trasmittivity as metamaterial atoms and their behavior as photonic molecules in the near-field of randomly fluctuating sources
Manuel Nieto-Vesperinas, Juan Miguel Aunon, F. J. Valdivia-Valero

Numerical simulations of microwave and NIR transmission in composites of high refractive index dielectric cylinders at frequencies of dipolar electric and magnetic resonances, show strong scattering losses bonding and antibonding of particle optical molecules is determined by the coherence length of random light.

09:30 : Multiple magnetic mode-based fano resonance in split-ring resonator/disk nanocavities
Qing Zhang, Xinglin Wen, Guangyuan Li, Qifeng Ruan, Jianfang Wang, Qihua Xiong

The high-order magnetic modes are observed in SRRs by polarization-resolved transmission spectroscopy. When a disk is centered within the SRRs, multiple high-order magnetic modes are coupled to a broad electric dipole mode of SRR/D, leading to significant Fano resonance spectral features in near-IR regime. The strength and line shape of the Fano resonances are tuned through varying the SRR split-angle and interparticle distance between SRR and disk. Finite-difference-time-domain (FDTD) simulations are conducted to understand the coupling mechanism.

08:30 - 10:00 — LT5

Session 3A7

Acoustic and Elastic Metamaterials I

Organized by: Yoon Young Kim and Jensen Li

Chaired by: Yoon Young Kim and Jensen Li

08:30 : Invited talk
From acoustic metamaterials to functional metasurfaces
Jun Xu, Chu Ma, Tian Gan, Anshuman Kumar, Narges Kaynia, Nicholas Fang

In this invited talk, we will present our research progress toward tailoring the edge rays and creeping rays

Wide band transparent metallo-dielectric nanowires at telecommunications wavelengths: more transparent than glass

R. Paniagua-Domínguez[1], D. R. Abujetas[1], L.S. Froufe-Pérez[1], J. J. Sáenz[2], and J. A. Sánchez-Gil[1]

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Abstract

In this paper we propose metallo-dielectric nanowires (NW) as structures suitable to construct electrically conducting nanowires which are transparent to infrared radiation at wavelengths used in telecommunication applications. We show that the transparency of metal NWs covered with high permittivity dielectric materials are optimal structures regarding fabrication imperfections, variations in the angle of incidence and polarization of the incoming radiation. The bandwidth of the transparent region entirely covers the near IR telecommunications range.

1. Introduction

Since several decades ago, different systems showing small light scattering efficiency has been proposed [1,2]. More recently, several nanometer sized structures have been studied and, even, experimentally demonstrated [3-7]. Those systems are based on the interaction of the electromagnetic modes in core-shell submicron sized particles. Even with relatively simple geometries, such as spherical or cylindrical core-shell structures, the degrees of freedom provided by size, available *realistic* materials and core-to-shell size ratios, are enough to obtain a global optical response with prescribed properties in a given frequency range.

Optically invisible metamaterial fibers [3], multishell cylindrical cloaking devices [4], metal coated dielectric invisible cylinders [5] or ZnO/Ag nanowire composites [6] have been recently proposed as cylindrical devices showing certain cloaking properties, or combining high transparency -low scattering- with other properties such as high electrical conductivity. One of the characteristics usually shared by many of the proposed systems is the resonant nature of the effect responsible for the transparency that, along with chromatic dispersion and absorption, lead to a narrowing of the transparency window.

2. Transparency of metallo-dielectric nanowires at telecommunications wavelengths

In this work, we analyze in detail the conditions required to obtain small scattering efficiency in a core-shell cylinder for any metal or dielectric combination in the infrared at bands relevant to telecommunications. By the use of a simple model based on the quasi-static approximation with radiative corrections to the polarizability (Fig. 1) of a core-shell cylinder [8], we obtain general properties required to achieve transparency in realistic structures [9].

We also check our predictions against a more accurate model based on Mie theory for cylinders[10]. Using this model, we obtain the scattering efficiency of optimized metal-dielectric NWs as a function of wavelength, angle of incicence and polarization.

Furthermore, by performing extensive Finite Element Method calculations on assemblies of core-shell NWs, we have determined the influence of fabrication errors on the transparency of the systems. We found that systems with up to 5% polydispersity in the size parameters defining the optimal transparency conditions do not significantly spoil the behavior of the system.

Also, we have computed the effects derived from multiple scattering of light in dense random arrangements of core-shell cylinders. We found that the system preserves transparency even when the cylinders are placed deep in subwavelength proximity.

3. Conclusions

We find that, under rather general conditions, metal nanowires with high refractive index coating can show a transparency region which is more robust against fabrication defects (size polydispersity) than metal coated fibers. Also, it is shown that it is possible to obtain up to three orders of magnitude lower scattering efficiency ,compared with raw metal cylinders, in a band as wide as 20% of the central frequency, and with realistic materials (Si coated Ag wires) in the infrared (See figure 1). The transparency condition is also quite robust regarding the angle of incidence and polarization of the incoming signal [9].

It is shown that the near field scattering is extremely weak in the transparency region. Hence, the coupling through evanescent modes among equal cylinders is essentially negligible. Then, a high density assembly of appropriately designed nanowires present a extremely low scattering efficiency [9]. Even the wavefronts are negligibly disturbed in a random and high density assembly of transparent nanowires.

Interestingly, the scattering efficiency of a dielectric-coated metal NW can be smaller than an equivalently thick glass slab.

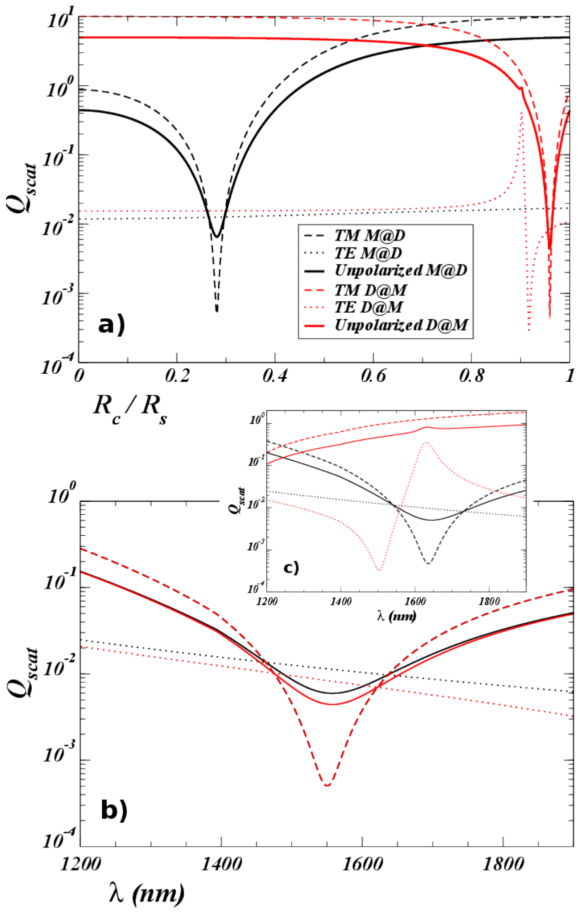

Figure 1: *Approximate scattering efficiency Q_{scat} as obtained from the quasi-static approximation. TM polarization (dashed line), TE polarization (dotted line) and unpolarized (continuous line) radiation is considered for both Ag@Si (black curves) and Si@Ag (red curves) structures. In a) Q_{scat} at a constant wavelength λ=1550 nm is plotted as a function of the core to shell radii ratio. In b), the spectra for the different polarization is presented. The ratio Rc/Rs is fixed in such a way that Q_{scat} is minimized in TM polarization for each structure. In the inset c), the core radius is reduced by 5%.*

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References

[1] H. Chew, M. Kerker, Abnormally low electromagnetic scattering cross sections, *Journal of the Optical Society of America* 5: 445-449, 1976.

[2] M. Kerker, Invisible bodies, *Journal of the Optical Society of America* 65: 376–379, 1975.

[3] A. Tuniz, B. T. Kuhlmey, P. Y. Chen, S. C. Fleming, Weaving the invisible thread: design of an optically invisible metamaterial fibre, *Optics express* 18: 18095–18105, 2010.

[4] P. Mundru, V. Pappakrishnan, D. Genov, Material- and geometry-independent multishell cloaking device, *Physical Review B* 85: 045402 1-8**,** 2012.

[5] P. Fan, U. K. Chettiar, L. Cao, F. Afshinmanesh, N. Engheta, M. L. Brongersma, An invisible metal-semiconductor photodetector, *Nature Photonics* 6: 380–385, 2012.

[6] Areum Kim, Yulim Won, Kyoohee Woo, Chul-Hong Kim, Jooho Moon, Highly transparent low resistance ZnO/Ag nanowire/ZnO composite electrode for thin film solar cells, *ACS Nan*o 7: 1081–1091, 2013.

[7] R. Paniagua-Domínguez, F. López-Tejeira, R. Marqués, J. A.Sánchez-Gil, Metallo-dielectric core-shell nanospheres as building blocks for optical three-dimensional isotropic negative-index metamaterials, *New Journal of Physics* 13: 123017, 2011.

[8] S. Albaladejo, R. Gómez-Medina, L. S. Froufe-Pérez, H. Marinchio, R. Carminati, J. F. Torrado, G. Armelles, A. García-Martín, J. J. Sáenz, Radiative corrections to the polarizability tensor of an electrically small anisotropic dielectric particle, *Opt. Express* 18. 3556–3567, 2010.

[9] R. Paniagua-Domínguez, D. R. Abujetas, L.S. Froufe-Pérez, J. J. Sáenz, J. A. Sánchez-Gil, Broadband telecom transparency of semiconductor-coated metal nanowires: more transparent than glass, Optics Express 21: 22076-22089, 2013.

[10] C. F. Bohren and D. R. Huffman, *Absorption and Scattering of Light by Small Particles*, John Wiley &Sons, New York, 1998.